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Scale-dependency of macroinvertebrate communities: Responses to contaminated sediments within run-of-river dams

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ABSTRACT

Due to their nutrient recycling function and their importance in food-webs, macroinvertebrates are essential for the functioning of aquatic ecosystems. These organisms also constitute an important component of biodiversity.

Sediment evaluation and monitoring is an essential aspect of ecosystem monitoring since sediments represent an important component of aquatic habitats and are also a potential source of contamination. In this study, we focused on macroinvertebrate communities within run-of-river dams, that are prime areas for sediment and pollutant accumulation. Little is known about littoral macroinvertebrate communities within run-of-river dam or their response to sediment levels and pollution. We therefore aimed to evaluate the following aspects: the functional and structural composition of macroinvertebrate communities in run-of-river dams; the impact of pollutant accumulation on such communities, and the most efficient scales and tools needed for the biomonitoring of contaminated sediments in such environments. Two run-of-river dams located in the French alpine area were selected and three spatial scales were examined: transversal (banks and channel), transversal × longitudinal (banks/channel × tail/middle/dam) and patch scale (erosion, sedimentation and vegetation habitats). At the patch scale, we noted that the heterogeneity of littoral habitats provided many available niches that allow for the development of diversified macroinvertebrate communities. This implies highly variable responses to contamination. Once combined on a global 'banks' spatial scale, littoral habitats can highlight the effects of toxic disturbances.

1. Introduction

1.1. Research context

Considering that only 0.014% of Earth's water occurs in the biosphere, water should be regarded as a limiting resource (Gleick, 1993). An increasing need for water resources for human populations, agriculture and energy production has induced an excessive development of dams or weirs, resulting in many hydromorphological or chemical disturbances of river systems (Zwick, 1992; Ward and Stanford, 1995; Bredenhand and Samways, 2009). The presence of a dam disrupts river continuity (Stanford et al., 1996; Poff et al., 1997; Born et al., 1998) and results in the accumulation of sediment within impoundments, thus limiting sediment transport further downstream. This accumulated sediment becomes a sink and a source of historic contamination. Sediments have a strong adsorption capacity for pollutants (Cairns et al., 1984; Chapman, 1990; Estebe et al., 1997), with contamination levels often being greater within sediments than in the whole water column (Chapman, 1992). Moreover, when disturbed and resuspended, sediments can release adsorbed contaminants into the water-column, resulting in further dispersal within the run-of-river dam and in downstream ecosystems. Historical contamination is thus a real threat to the ecological integrity of many aquatic ecosystems (Sheppard, 2005; Norris et al., 2007; Johnston and Roberts, 2009).

1.2. Biomonitoring of contaminated sediment

Contaminants stored within sediments exert a persistent pressure, which implies chronic and sublethal responses that impact on macroinvertebrate communities (Field and Pitt, 1990; Beyer et al., 2000; Viganò et al., 2002). The effects of these contaminants may, however, extend beyond sediment habitats as they can be transferred to other components of aquatic habitats — for example, into the water

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column (Larsson, 1985; Asare et al., 2000; Coulthard and Macklin, 2003). For all these reasons, various biomonitoring tools have been developed for the study of contaminated sediments. Sediment toxicity is normally assessed by means of biotests carried out in laboratories. Such tests do not, however, adequately account for responses at the community level (Lafont et al., 2007). Because contamination can induce modifications in ecosystem's processes, thus affecting ecosystem integrity (Kiffney and Clements, 1994), it is necessary to focus on community- and ecosystem-contamination levels. Triadic studies that combine chemical, ecotoxicological and ecological approaches to evaluate sediment toxicity appear to be more appropriate tools than 'traditional' laboratory evaluations, but such studies still neglect ecosystem functioning (Long and Chapman, 1985; Borgmann et al., 2001; Sorensen et al., 2007). Despite these challenges associated with sediment biomonitoring, sediment storage – the principal concern of the present paper – is rarely studied, partly because storage is not considered within legal texts. This is surprising, considering that 60,000 dams are referenced in France. There is a paucity of knowledge of the impacts of contaminated sediments on macroinvertebrate communities (Ramsey et al., 2005); thus, attempting to understand such impacts on the community structure and functioning of run-of-river dams is an important challenge.

In this context, we aimed to assess structural and bio-ecological responses to contamination across several spatial scales, by means of various ecological indicators. We hypothesized that: (i) invertebrate communities should respond functionally and structurally to sediment contamination, but we forecast multiple responses according to various spatial scales; and (ii) when contamination is low, community response to pollutants should be overshadowed by habitat heterogeneity.

2. Material and methods

2.1. Sampling design

2.1.1. Study area and contamination status

Two run-of-river dams on a French alpine river – the name of which has not been given because of confidentiality agreements with the hydroelectric company exploiting the dams – were selected to examine macroinvertebrate composition associated with various levels of sediment contamination. The catchment area is predominantly industrial and urbanized, inducing an accumulation of metallic pollutants in the sediment of two successive hydroelectric dams. The physico-chemical characteristics of the sediments and the water column were assessed in samples realized during the field campaign and sent to a specialized laboratory. PCBs and most of PAHs in the dams were below detection limits, and organic contamination was low. Monitoring of physicochemical parameters, such as dissolved oxygen concentration, temperature and conductivity, was also undertaken (Table 1). The data indicated differences in metallic contamination between the two systems.

2.1.2. Macroinvertebrates sampling

Macroinvertebrates were sampled in May 2008 using a newly-designed sampling protocol. To distinguish influences of various hydraulic and hydro-morphological conditions, sediment accumulation areas associated with run-of-river dams were subdivided into three zones, termed 'tail', 'middle' and 'dam'. The 'tail' is closest to river conditions, the 'dam' is typical of a lentic system and the 'middle' exhibits intermediate characteristics. Similarly, communities of the banks and of the channel were sampled separately. Habitats on each bank were described prior to sampling macroinvertebrate communities using a Surber net (mesh size 500 μm, sampled area 0.05 m^2). Macroinvertebrates in the channel were sampled by means of dredging from a boat perpendicular to a transect in each of the three areas defined above. For each transect, the left side, the middle and the right side of the channel were sampled. Samples were preserved in 4% formalin in the field and then transferred to the laboratory where they were sieved and sorted, and identified to genus level — using Tachet et al. (2000). Diptera were, however, identified to family and tribe level and Oligochaeta and Nematoda to higher taxonomic levels. Individuals within each taxon were then counted.

2.2. Data analysis

Three spatial scales were investigated: a) transversal scale: samples pooled according to their bank or channel origin; b) transversal × longitudinal scale: samples pooled according to the two factors considered together, for instance banks × tail; and c) patch scale: samples pooled according to habitat type (categorized as 'erosion', 'sedimentation' or 'vegetation'). For each scale, data were explored using three types of indicators: structure indices, taxonomic assemblages, and bio-ecological traits structure.

Richness, abundance, proportion of main groups (EPT, Diptera, Mollusca, and Crustacea), Shannon and Weaver diversity indices, Simpson Evenness Index, and Rao Functional Diversity Index (Lavorel et al., 2008; de Bello et al., 2009) were calculated. The functional diversity represents the overall differences among species in a community according to their traits. We applied this index to the distribution of categories within 22 traits (Table 2) describing biological and ecological traits of macroinvertebrates (Usseglio-Polatera et al., 2000). At the transversal scale, Principal Component Analysis (PCA) was used to investigate differences between run-of-river dams. At the patches scale, the interaction between the two tested parameters (habitat type and contamination status) was also assessed using ANOVA (normal distribution and homoscedasticity respected when the two factors are considered). Student's t-test and Mann–Whitney test were used to identify the intra-factor differences (when factors are considered independently, parametric conditions were not always respected). The vegetation habitat type was not investigated because the number of sampled substrates was too low in the reference run-of-river dam.

Table 1
Principal physico-chemical parameters characterizing contamination of sediments and the water column.

Contaminant concentrations in sediments															
	Metals (mg $kgDW^{-1}$)										PAH (μg $kgDW^{-1}$)				
	Al	Fe	Cr	Co	Cu	Mn	Ni	Pb	Zn	As	BaP	BaA	BgP	Fluo	Ind
Reference site	9.2×10^3	6.5×10^3	38	4	14	169	7.7	22.5	90	1.9	18	24	27	101	24
Contaminated site	19.7×10^3	15×10^3	83.5	9	31	423	54.7	17.8	108	1	18	24	27	98	25
Water chemistry															
	Cond. μS cm^{-1}	pH	Temp. °C	O_2	COD	DBO	Ca	Mg	K	NH_4	Cl	NO_3	NO_2	SO_4	PO_4
				mg l^{-1}											
Reference site	411	8.2	18.7	8.6	1.9	1.5	70	5	2	0.32	15	16	0.28	15	0.22
Contaminated site	390	8.15	17.6	9.2	1.8	0.9	68	5	1.7	0.13	13	9.9	0.11	14	0.25

Table 2
The 22 biological and ecological traits used in the analysis, and their categorization.

Biological traits	Categories	Ecological traits	Categories
Maximal size (cm)	≤0.25	Transversal distribution	River channel
	>0.25 to 0.5		Banks, connected side-arms
	>0.5 to 1		Ponds, pools, disconnected side-arms
	>1 to 2		Marshes, peat bogs
	>2 to 4		Temporary waters
	>4 to 8		Lakes
	>8	Longitudinal distribution	Groundwaters
Life span (year)	≤1		Crenon
	>1		Epirithron
Number of reproductive cycles per year	<1		Metarithron
	1		Hyporithron
	>1		Epipotamon
Aquatic stages	Egg		Metapotamon
	Larva		Estuary
	Nymph		Outside river system
	Adult	Altitude	Lowlands
Reproduction	Ovoviviparity		Piedmont level
	Isolated eggs, free		Alpine level
	Isolated eggs, cemented	Biogeographic area	Pyrenees
	Clutches, cemented or fixed		Alps
	Clutches, free		Vosges, Jura, Massif Central
	Clutches, in vegetation		Lowlands (oceanic)
	Clutches, terrestrial		Lowlands (Mediterranean)
	Asexual reproduction		Flags/boulders/cobbles/pebbles
Dispersal	Aquatic passive	Substrate preferences	Gravel
	Aquatic active		Sand
	Aerial passive		Silt
	Aerial active		Macrophytes
Resistance forms	Eggs, statoblasts		Microphytes
	Cocoons		Twigs/roots
	Housings against desiccation		Organic detritus/litter
	Diapause or dormancy		Mud
	None	Current velocity	Null
Respiration	Tegument		Slow (<25 cm/s)
	Gill		Medium (25–50 cm/s)
	Plastron		Fast (>50 cm/s)
	Spiracle	Trophic status	Oligotrophic
	Hydrostatic vesicle		Mesotrophic
Locomotion	Flier		Eutrophic
	Surface swimmer	Salinity (preferences)	Freshwater
	Full water swimmer		Brackish water
	Crawler	Temperature	Psychrophilic (<15 °C)
	Burrower		Thermophilic (>15 °C)
	Interstitial		Eurythermic
	Temporarily attached	Saprobity	Xenosaprobic
	Permanently attached		Oligosaprobic
Food	Microorganisms		β-Mesosaprobic
	Detritus (<1 mm)		α-Mesosaprobic
	Dead plant (>=1 mm)		Polysaprobic
	Living microphytes	Low pH sensitivity	≤4
	Living macrophytes		>4 to 4.5
	Dead animal (>=1 mm)		>4.5 to 5
	Living microinvertebrates		>5 to 5.5
	Living macroinvertebrates		>5.5 to 6
Feeding habits	Vertebrates		>6
	Absorber		
	Deposit feeder		
	Shredder		
	Scraper		
	Filter-feeder		
	Piercer		
	Predator		
	Parasite		

Taxonomic composition and bio-ecological structure were also investigated. For each spatial scale, the abundances of taxa were log-transformed and analyzed using Correspondence Analysis (CA). For the functional structure, the biological and ecological categories of traits were weighted by the log-transformed abundance of each taxon. Therefore, for each trait category, the sum of weighted scores was expressed as relative abundance distribution within a trait (Thioulouse et al., 1997). We analyzed the frequencies of the categories using Fuzzy Correspondence Analysis (FCA). We used R software (R development Core Team, 2008) and the ADE4 library (Chessel et al., 2004) for all statistical analysis.

3. Results

3.1. Selection of relevant spatial scales

To select the most relevant spatial scales, permutation tests were realized on the multivariate analysis performed at the three spatial scales. They test the null model, i.e. whether the structure of data links to a particular factor (in this case, the contamination level) or is only the result of stochastic processes. Results are synthesized in Table 3. Statistical analysis indicates that the transversal scale provides evidence of significant faunistic and functional differences between the two stations, while the patch scale discriminates the two stations only on the basis of indices. Lastly, the transversal × longitudinal scale does not highlight inter-site differences. For these reasons, only results obtained for transversal and patch scales are detailed below.

3.2. Response of indices to the two selected space scales

3.2.1. Transversal scale

The first axis of the PCA (Fig. 1a), based on various indices (Table 4a), separates the reference banks from channels and disturbed banks. Correlation circle results (Fig. 1b) indicate that this axis is strongly correlated with richness and diversity indices. This suggests that, even if the banks offer more habitats than the channel, the contaminated banks exhibit less than half the species occurring in the reference banks and, on average, as many species as found in the channel. Similar observations can be made with respect to taxonomic and functional diversities. The EPT (Ephemeroptera, Plecoptera and

Table 3
p-Value results for permutations (Monte Carlo tests) carried out on multivariate analyzes, corresponding to spatial scales and indices, taxonomic or functional indicators.

Scale	Indices	Faunistic assemblages	Bioecological traits
Transversal	p-value = 0.001	p-value = 0.001	p-value = 0.004
Longitudinal × transversal	NS	NS	NS
Patches	p-value = 0.03	p-value = 0.001	p-value = 0.002

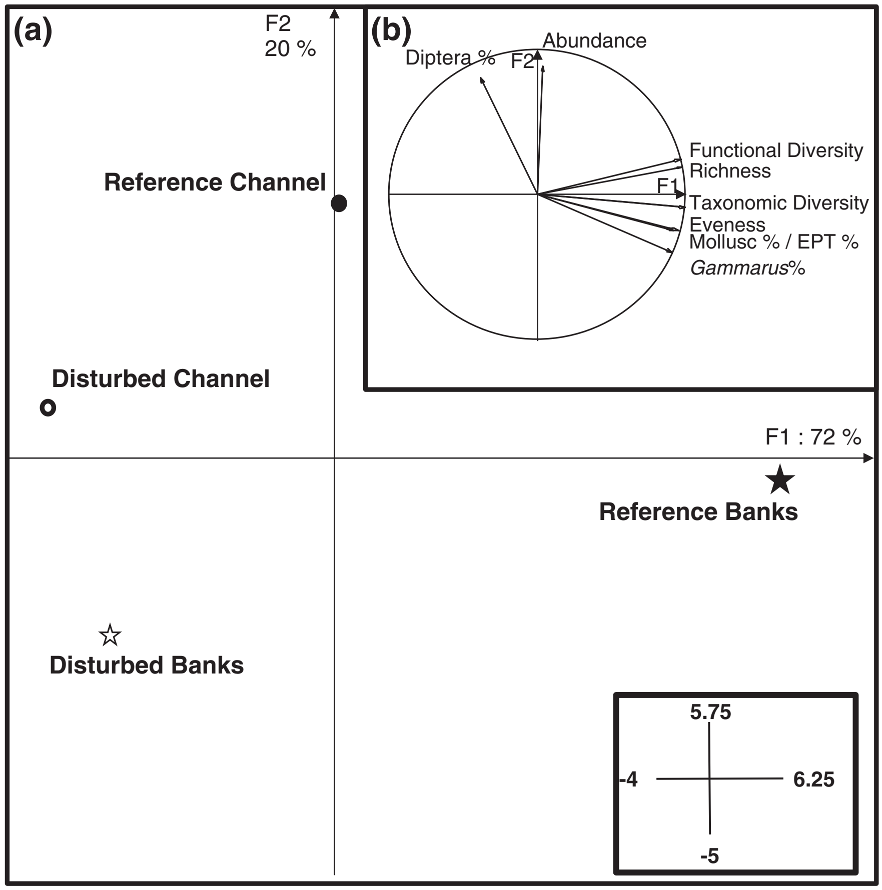

Fig. 1. PCA performed at the transversal scale on the indices table: (a) factorial plane of two run-of-river dams, and (b) correlation circle for the nine indices. The circles and stars represent channel and bank samples, respectively; black and white symbols indicate the reference system and the disturbed system, respectively.

Trichoptera) and Mollusca have been more severely impacted by the disturbance. The second axis of the PCA defines an abundance gradient positively correlated with the reference channel. Thus, the reference run-of-river dam is characterized by rich and diverse littoral communities and high abundances in the channel. In contrast, the analysis indicated impoverished communities within disturbed banks. In spite of a marked reduction of abundance, the 'disturbed channel' seems less disturbed than the contaminated banks, the indices of the former being similar to those of the reference channel. To some extent, at this level of investigation, channels show structural similarities whereas the banks index distinguishes both of the run-of-river dams.

Table 4
Mean ± standard deviation values of (a) the nine indices calculated at the transversal scale and (b) the four indices calculated at the patch scale.

	Banks		Channel	
	Reference	Contaminated	Reference	Contaminated
(a)				
Richness	20 ± 8	10 ± 2	16 ± 6	10 ± 6
Abundance	746 ± 578	619 ± 604	4347 ± 4665	595 ± 733
EPT %	25 ± 24	5 ± 6	5 ± 8	12 ± 19
Diptera %	27 ± 18	22 ± 12	61 ± 26	52 ± 34
Mollusc %	3 ± 4	0.59 ± 0.84	1 ± 2	0.48 ± 0.78
Gammarus %	20 ± 21	17 ± 18	6 ± 8	6 ± 12
Functional diversity	0.72 ± 0.16	0.56 ± 0.29	0.56 ± 0.27	0.51 ± 0.28
Taxonomic diversity	2.57 ± 0.73	1.83 ± 0.96	1.83 ± 1	1.71 ± 1
Equitability	0.42 ± 0.12	0.30 ± 0.16	0.30 ± 0.17	0.28 ± 0.18
	Erosion		Sedimentation	
	Reference	Contaminated	Reference	Contaminated
(b)				
Richness	19 ± 6	15 ± 4	15 ± 4	7 ± 2
Abundance	1553 ± 3461	220 ± 81	3965 ± 3873	812 ± 733
Functional diversity	0.71 ± 0.26	0.81 ± 0.03	0.57 ± 0.06	0.33 ± 0.2
Faunistic diversity	2.61 ± 1	2.89 ± 0.28	1.70 ± 0.33	1 ± 0.65

3.2.2. Patches scale

Depending on contamination status and habitat type, the responses of richness, abundance, taxonomic and functional diversities, were tested using ANOVA. The absence of a significant interaction between the factors (Table 5) permits us to test them independently. All variables responded significantly to habitat type (Table 5). Conversely, at the patches scale, only richness discriminated toxic contamination status. Results, summarized in Table 4b, indicate that the sedimentation habitats at the 'disturbed' station are impoverished, which can be related to the accumulation of metals in the sediments.

Table 5
Habitat and contamination effects at the patch scale on four structural and compositional indices. Interaction was assessed by ANOVA. Status and habitat effect were investigated using the Mann and Whitney test, except for values in bold, for which a Student's t test was performed.

Variables	Interaction	Status factor	Habitat factor
Abundance	$p = 0.44$	$p = 0.46$	$p = 0.03$
Richness	$p = 0.57$	**$p = 0.01$**	**$p < 0.001$**
Taxonomic diversity	$p = 0.17$	$p = 0.17$	$p < 0.001$
Functional diversity	$p = 0.06$	$p = 0.19$	$p < 0.001$

3.3. Taxonomic structure versus bio-ecological structure

3.3.1. Transversal scale

The first axis of the correspondent analysis (Fig. 2) shows differences, in terms of taxa assemblages, between reference dams and disturbed run-of-river dams. The second axis reveals similarities between banks and channels in the reference system, while differences are evidenced in the 'disturbed' sample. According to the fuzzy coding analysis (Fig. 3), the relative importance of the two factors (transversal localization and contamination status) is inverted when compared to the taxonomic analysis. The first axis indicates that assemblages are functionally similar in banks and channels in the reference system and different in the contaminated system, while the second axis separates the contamination level. Moreover, the percentage of explained variance is higher (77% versus 44%) when using the fuzzy coding analysis.

3.3.2. Patches scale

The main factor controlling functional analysis is the habitat type instead of the contamination (Fig. 4). The factorial plane F1F2 provides evidence that differences between samples were governed by the habitat type, with discrimination along the F1 axis. Conversely, within a habitat type, no differences are observed according to the contamination status. Similarly, analysis of the faunistic assemblage does not reveal significant responses. As was found in the analysis of various indices, at this scale, differences between habitats rather than between contamination status are indicated.

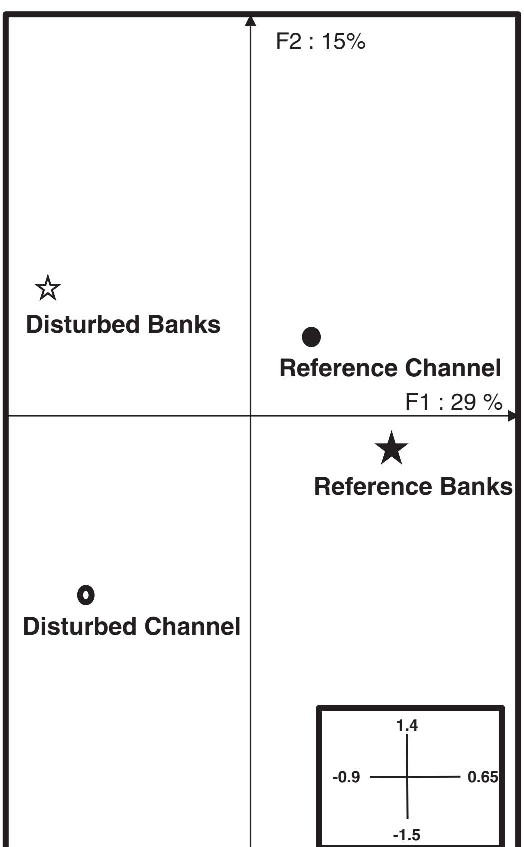

Fig. 2. Factorial plane of Correspondence Analysis performed at the transversal scale on the faunal list with log-transformed abundances. The circles and stars represent channel and bank samples, respectively; black and white symbols indicate the reference system and the disturbed system, respectively.

4. Discussion

4.1. Spatial scale

Because observation scale governs our ability to detect and explain the impacts of contamination on macroinvertebrate communities, it is important to determine which spatial scale, and which indicators (indices, taxonomic, and bio-ecological traits) are the most useful and efficient for detecting the consequences of sediment contamination. This is important for the development of suitable tools for the biomonitoring of sediment contamination.

4.1.1. Transversal scale

Results demonstrated that macroinvertebrate communities associated with banks are suitable for indicating the effects of contamination, in contrast to those of channel habitats. At this spatial scale, between-station differences associated with contamination levels over-ride within-station substrate heterogeneity effects. Moreover, the habitat constraint is weaker in banks, that have higher levels of diversity in terms of niches and macroinvertebrate communities (Heino, 2000; Harrison and Hildrew, 2001). This explains why banks, in comparison with channels, are more prone to differences between sites with various contamination levels. Being located at the land/water interface, banks play a key role in the ecosystems' processes. This emphasizes the importance of knowledge of the structure and functioning of the littoral environment. For example, the bank area in lakes has been identified as an important hydro-morphological component supporting ecological quality (Naiman and Décamps, 1997; Rowan et al., 2006; Elosegi et al., 2010). Free et al. (2009) demonstrated the close association of ecotone integrity to fulfilling the habitat requirements of mayfly adults. James et al. (1998) insist on the importance of this habitat for overall production and in terms of allochthonous carbon contribution to the system.

4.1.2. Patches scale

In contrast with the results of studies of river systems (Pardo and Armitage, 1997), our analysis at the patches scale was not relevant for discriminating contamination effects. This could be explained by the extreme variability and complexity of patch communities, which reduces the sensitivity of impact detection (Donohue et al., 2009). Our study reveals that taxonomic and bioecological structures of macroinvertebrate communities were mostly governed by habitat type, while contamination only influenced richness. Since few studies have focused on run-of-river dams, we can only compare our results to those obtained from lakes or ponds. Nevertheless, even in those systems, few studies have focused on the use of littoral habitats for ecological assessment. Even though White and Irvine (2003) recommend that sampling strategies should be based on pebble or boulder habitats, our results indicated no significant interactions between habitat type and contamination. This could, however, be explained by the analytical strategy, all erosion habitats being pooled. Smaller scales should also enhance such information.

As Levin (1992) noted, "The key for understanding how information is transferred across scales is to determine what information is preserved and what information is lost from one scale to the other". We observed that our ability to find evidence for a response of communities to contaminated sediment depends on the level at which the observations are made. Our results suggest that focusing sampling effort on banks is relevant and practical for the biomonitoring of contaminated sediment.

4.2. Indicator scales

Previously, only taxonomic responses to environmental variables and to contamination have been evaluated, with the consensus that the loss of species is associated with disturbances of the ecosystem.

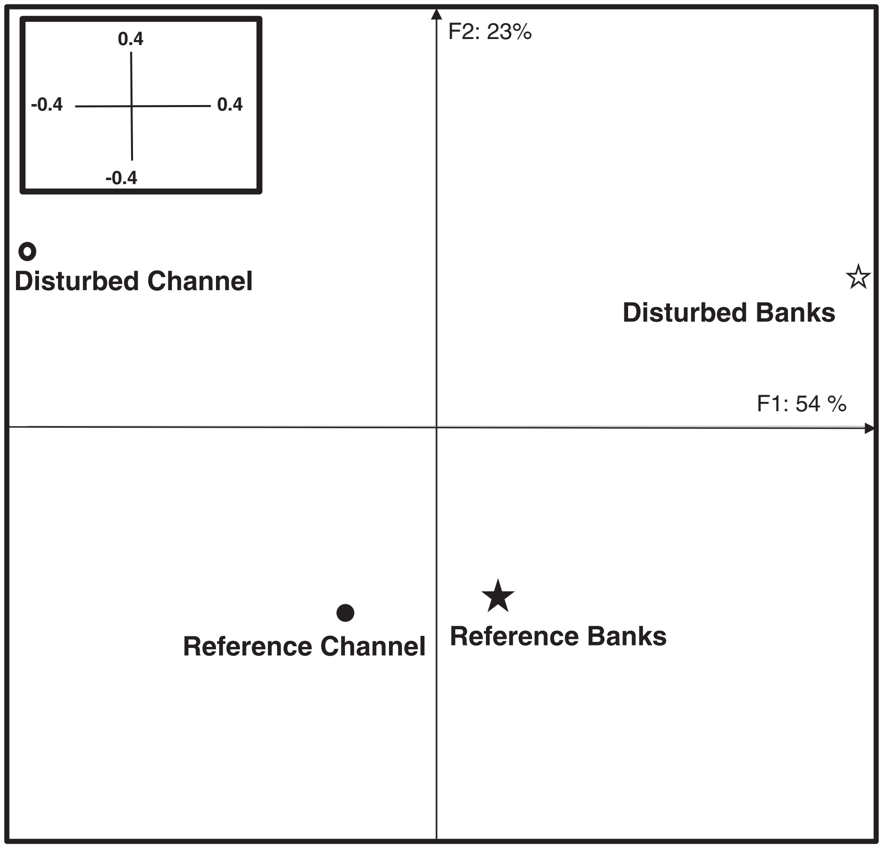

Fig. 3. Factorial plane of the Fuzzy Coding Analysis performed at the transversal scale on the bioecological traits. The circles and stars represent channel and bank samples, respectively; black and white symbols indicate the reference system and the disturbed system, respectively.

Changes in the distribution and abundance of one species can, however, result in disproportionate and unexpected responses of other species due to attempts to compensate functional changes within the community (Naeem, 1998). This suggests that studying spatial scales will not be enough, and that it is also necessary to consider relevant indicators in order to identify and evaluate perturbations. Indeed, when we use taxonomic or functional indicators, we do not necessarily observe the same response: the loss of species does not systematically imply a response of the functional structure. Different species may appear to perform the same function (i.e. be redundant) under a restricted set of conditions, yet their functional roles may vary in naturally-heterogeneous environments (Walker, 1992; Wellnitz and Poff, 2001). Traits are one of the tools developed to investigate functional characteristics of a community. By definition, a trait is a surrogate of an organism's performance and/or its individual fitness (Violle et al., 2007). Numerous studies have demonstrated the ability of biological and ecological traits to discriminate metallic (Archaimbault et al., 2010), hydraulic (Snook and Milner, 2002; Griswold et al., 2008) or organic (Charvet et al., 1998) perturbations. In the same way, even if we had observed responses, in terms of species composition, to contamination, our results would still indicate the relevance of bioecological structure, which is a better indicator of the impact of contamination in run-of-river dams. Nevertheless, this trait-based approach assumes that these biological and ecological parameters (autoecology of species) are relevant indicators of species' functions within the community. The concept of 'trait' is particularly important when referring to functional traits (Chapin et al., 2000). Potentially, the traits defined by Usseglio-Polatera et al. (2000) could be considered to be functional traits within ecosystem communities, because the changes that they describe could directly affect ecosystem processes through changes in biotic controls (i.e. predation) and indirectly through changes in abiotic controls (i.e. availability of limiting resources). For example, in the case of species traits that relate to food resources and habits, habitat use and dispersal capacities could be regarded as responses to contamination, while driving changes in ecosystem processes. In the same way, life history traits related to demographic parameters (life cycle, fecundity, maximum size, and number of generations) could be affected by metallic contamination and could thus indirectly alter ecosystem functioning by cascade effects (Zavaleta et al., 2009). Traits described in this article are potential traits based on the literature, and are regarded as 'response traits', i.e. a measure of how the trait assemblages react to environmental parameters at the community level. This response may or may not be correlated with the effects on functional processes. It is thus necessary to discern, and be cautious of, the notions of functional response traits and functional effect traits (Lavorel and Garnier, 2002; Violle et al., 2007). Future research should also assess ecosystem's processes, to compare ecosystem functional responses to variations in community traits, in order to identify whether functional traits in response to, and/or as an effect of, contaminated sediment can be defined.

4.3. Ranking impacts

Our results led us to wonder about the hierarchy of impacts, i.e. whether physical constraints could mask the effects of a moderate toxic contamination. Water flow governs the fundamental nature of streams and rivers (Poff et al., 1997; Hart and Finelli, 1999), so modifications of flow, caused by dams, alter the structure and function of river ecosystems (Malmqvist and Englund, 1996; Hart et al., 2002). However, very few studies have concentrated on the adverse effects of dams on the physical, chemical and biological characteristics of rivers (Poff and Hart, 2002). The presence of dams implies two perturbation types: a physical disturbance due to sediment accumulation and the

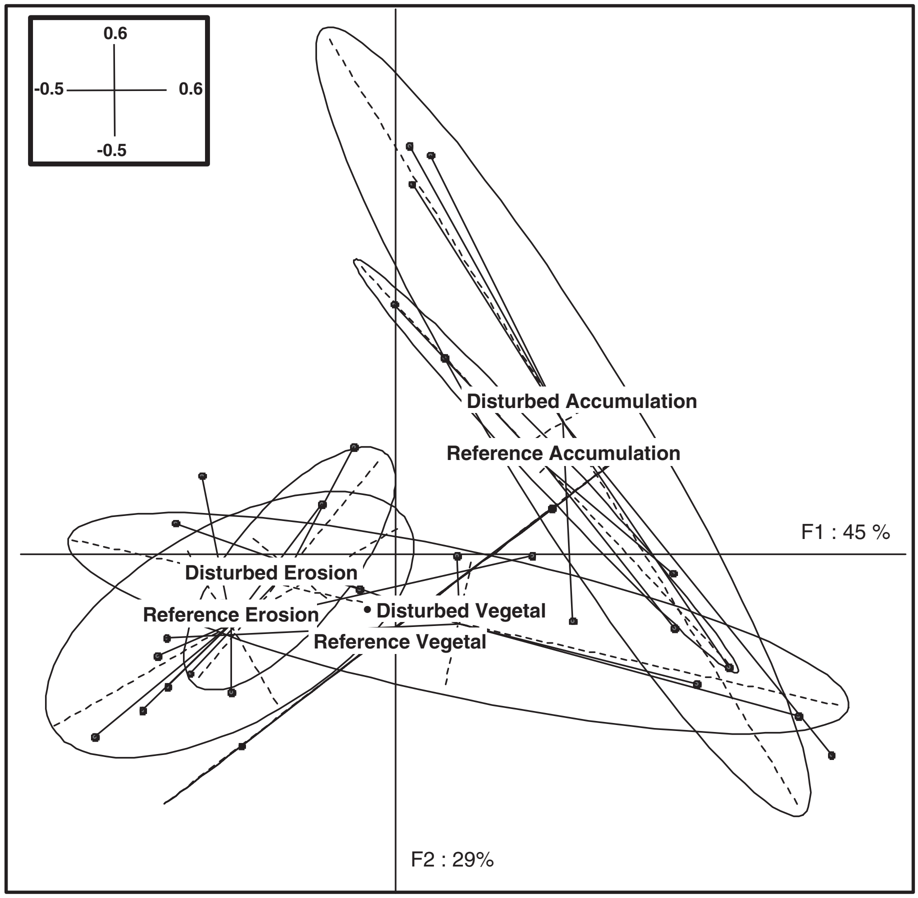

Fig. 4. Factorial plane of the Fuzzy Coding Analysis performed at the patch scale on bioecological traits.

modification of river flow; and a toxic disturbance, due to potential pollutant accumulation within sediments. These perturbations cannot be dissociated in the present study of communities in run-of-river dams. The results obtained for the two studied systems revealed that habitat characteristics of the channel are more significant than differences related to contamination levels between the dams. No clear pattern was, however, indicated, highlighting the need to consider the dams-and-rivers continuum as a means of discriminating these two sources of community modification.

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